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RESEARCH DEPARTMENT REPORT

Compatibility of Band II broadcast transmissions at frequencies below 105 MHz with private mobile radio in the Band 105–108 MHz

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COMPATIBILITY OF BAND II BROADCAST TRANSMISSIONS AT FREQUENCIES BELOW 105 MHz WITH PRIVATE MOBILE RADIO IN THE BAND 105–108 MHz

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Summary

Consideration is given to the problems that may arise with the operation of Private Mobile Radio (PMR) receiving base-stations using the frequency band 105–108 MHz in proximity to broadcast transmitters in Band II. The existing criteria for the protection of the Broadcasting Service from land mobile services and the protection of PMR from broadcast transmitters are given. Measurements made to assess the characteristics of both broadcast transmitters and PMR base-station receivers provide new results for the levels of transmitter sideband noise and spurious emissions, and for the susceptibility of the base-station receivers to adjacent-channel interference. These show that the existing ITU sharing criteria for broadcast and mobile services in closely-spaced frequency bands are necessary but are insufficient to permit co-ordinated planning of these services on a non-interference basis. New results in this Report, show the importance of taking these factors into account when planning these services.

Issued under the Authority of

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1. Introduction

The World Administrative Radio Conference held at Geneva in 1979 extended the v.h.f./f.m. broadcast band to 108 MHz and allocations in the extended band were made at a Regional Administrative Conference in 1984. In the United Kingdom there are a number of permitted services within the broadcast band. In particular the frequency band 105 MHz to 108 MHz is used for Private Mobile Radio (PMR) services controlled by the Joint Radio Committee (JRC) of the nationalised industries of fuel, power and transport. These services have security of tenure of the frequency band until 31st December 1995, although they will not be protected against interference from foreign broadcast transmissions after 1st January 1991. Accordingly, there will be a number of years when the two services must co-exist in the same band at closely-spaced frequencies.

The JRC services in the band 105–108 MHz use mobile transmission, base-station reception. It is therefore necessary, in general, to consider interference from the mobile transmitter to the domestic broadcast receiver and from the broadcast transmitter to the base-station receiver of the mobile service.

The ITU has adopted sharing criteria for the mutual protection of the Broadcasting Service and the Land Mobile Service. These may require more stringent control of radiated noise and intermodulation levels from broadcast transmitters and have prompted an investigation to determine transmitter output characteristics and the susceptibility of the PMR base station receivers to adjacent-channel interference. Results of these measurements are presented in this Report.

2. Existing criteria

2.1 Mobile transmission interfering with broadcast reception

The sharing criterion adopted by the ITU (1982) to protect the broadcasting service from interference from the land mobile service within or immediately adjacent to the coverage area of the broadcasting transmitter is the following:[1]

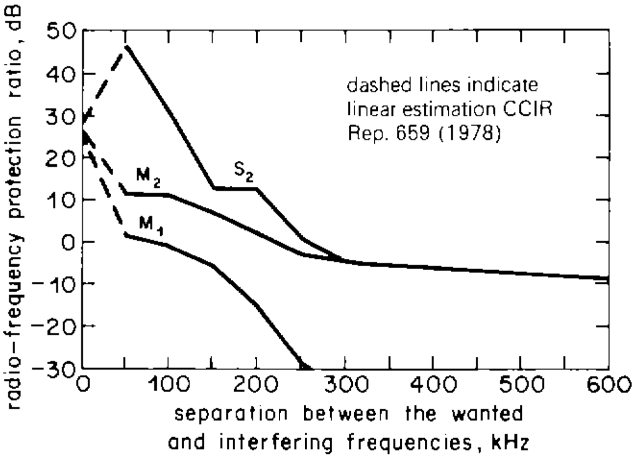

Fig. 1 – Radio-frequency protection ratios for interference into broadcast reception.
M1: Monophonic reception (unwanted signal: f.m., modulation index: m = 1)
M2: Monophonic reception (unwanted signal: a.m., modulation depth: m = 95%, Receiver input 1 mV)
S2: Stereophonic reception (unwanted signal: a.m., modulation depth: m = 95%, Receiver input 1 mV)

- Minimum carrier frequency separation required in the same geographical area: 500 kHz

Otherwise, the protection ratios indicated in Fig. 1 are to be used.

No changes to these criteria were adopted at the 1984 Conference[2] and no new work on this mode of interference is given in this report.

2.2 Broadcast transmission interfering with base-station reception

The sharing criteria for the protection of the land mobile service in the band 104 to 108 MHz, adopted by the ITU,[1,2] are the following:

- Field strength to be protected: 15 dB (μV/m) at a height of 3 m

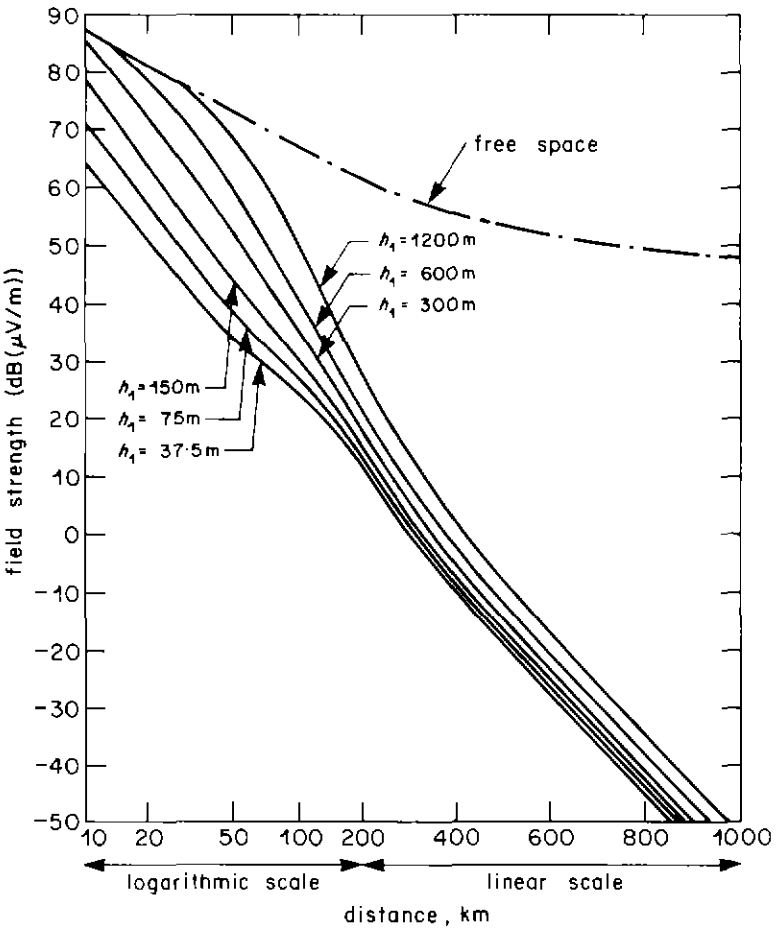

Fig. 2 – Propagation curves for the Broadcasting Service over land. Field strength dB(μV/m) for 1 kW e.r.p. which may be exceeded for 10% of the time at 50% of the locations, receiving aerial height 10 m.

- Height-gain to be assumed for a receiving antenna height change from 3 m to 10 m a.g.l.: 9 dB
- Protection ratio: See Table 1
- Propagation data to be used for sharing calculations: see Figs. 2 and 3
- Percentage of locations to be protected: 50%

Table 1 Protection Ratios for Land Mobile Services

Frequency separation between carriers of the two services (kHz)	Protection ratio for a.m. land mobile services (dB)	Protection ratio for f.m. land mobile services (dB)
0	18	8
25	16	6
50	4.5	– 5.5
75	– 7.5	–17.5
100	–17.5	–27.5

- Percentage of time to be protected: 90%
- Polarisation discrimination for horizontally polarised broadcasting emission: 18 dB base-station, 8 dB mobile station

For a mixed-polarised transmission only the vertical component of the transmission should be taken into account.

3. Nomenclature

For the remainder of the Report it is convenient to adopt the same nomenclature of interference modes as is used for consideration of compatibility with aeronautical navigation aids. Two general types of interference are distinguished. Components generated in the broadcast transmitter and aerial system and radiated at frequencies in adjacent-bands are called Type A interference. Components generated within the adjacent-band receiver from transmissions at broadcast frequencies are called Type B interference. In the former case any remedial measures must be taken at the broadcast station whereas in the latter case they must be taken at the adjacent-band receiver.

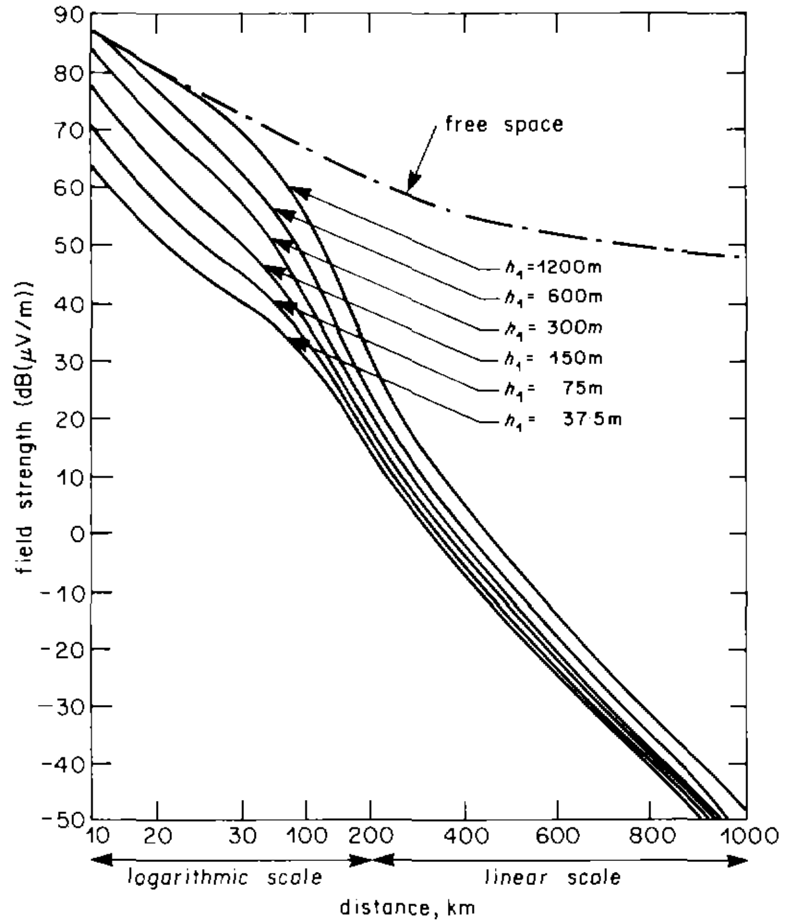

Fig. 3. – Propagation curves for the Broadcasting Service over cold sea. Field strength dB(μV/m) for 1 kW e.r.p. which may be exceeded for 10% of the time at 50% of the locations, receiving aerial height 10 m.

Both Type A and Type B interference mechanisms may be subdivided as follows:

Type A1: This is spurious emission from the broadcast station at frequencies within the adjacent-band. The most important source of A1 will be radiated intermodulation products where there are two or more broadcast frequencies.

Type A2: This is interference from the sidebands of a single broadcast transmitter outside the nominal modulation bandwidth but includes modulation components and the noise floor of the transmitter.

Type B1: This is interference resulting from broadcast transmissions intermodulating in the PMR receiver.

Type B2: In this mode the PMR receiver suffers overload by the broadcast transmission to the extent that its in channel performance is impaired, e.g. by reduction of sensitivity.

4. Type A1 interference: broadcast transmitter intermodulation

This has been the subject of a separate study in connection with aeronautical compatibility.[3]

A CCIR interim working party[4] has recommended reduced levels of spurious emissions from broadcasting stations falling in the band 108—137 MHz. Moreover the Geneva Conference[2] has recommended that Appendix 8 of the Radio Regulations[5] be modified* with a view to reducing the maximum permitted spurious emission power levels radiated in this band. It would be reasonable therefore, to assume that it should be possible to achieve these reduced levels where necessary when the intermodulation products fall in the band 105—108 MHz. The reduced levels are given in Table 2.

The following paragraphs have been taken from the draft recommendations in reference 4.

'The Recommendations relate to the total mean power level of all spurious components at any one frequency in the aeronautical band, supplied to the antenna system transmission line at f.m. broadcasting stations. The level is measured after all filters, combiners, multiplexers, etc. which may affect the radiated level of spurious emission.

To meet the Recommendations, the power level from an f.m. broadcasting station should not exceed

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*This proposal was opposed at the Final Meeting of CCIR SG10.

Table 2

Maximum relative level of spurious emissions

Transmitter power (kW)	ITU Requirement	JIWP Recommendations	JIWP Improvement required
0·01	−56 dB	−56 dB	0 dB
0.02	−59 dB	−59 dB	0 dB
0.1	−60 dB	−66 dB	6 dB
0·2	−60 dB	−69 dB	9 dB
1.0	−60 dB	−76 dB	16 dB
4.0	−66 dB	−82 dB	16 dB
10.0	−70 dB	−85 dB	15 dB
20.0	−73 dB	−85 dB	12 dB
40.0	−76 dB	−85 dB	9 dB

25 μW for transmitter powers up to approximately 8 kW.

Also the attenuation (mean power within the necessary bandwidth to the mean power of the spurious component concerned) for transmitter powers above approximately 8 kW should be at least 85 dB.'

It remains to determine the geographical separation between broadcast transmitter and base-station receiver for given degrees of suppression of intermodulation products.

The propagation curves shown in Fig. 2 relate to a receiving aerial height of 10 m a.g.l. whereas the mobile service is to be protected at 3 m a.g.l. even though base-station receiving aerials are normally higher than this.

Consider for example a broadcast transmitter having an e.r.p. of 1 kW and an effective aerial height of 75 m interfering with a base-station over a land path at a range of 10 km. From Fig. 2 the field strength at a receiving aerial height of 10 m will be +71 dB (μV/m). The predicted field strength at a height of 3 m is

$$+71 - 9 = +62\,\text{dB}\,(\mu\text{V/m}).$$

The field strength to be protected is +15 dB (μV/m) and the protection ratio for an a.m. service with carrier co-incidence is 18 dB. The required suppression of intermodulation products is then

$$-(62 - 15 + 18) = -65\,\text{dBc}.$$

where dBc is the ratio of the intermodulation product power level to carrier power level, in decibels.

This requirement is 5 dB more stringent than the Radio Regulations.[4] For higher broadcast transmitter powers or shorter distances a greater suppression would be needed. However, frequency co-incidence between the wanted PMR signal and the intermodulation product has been assumed and in many actual cases this will not apply or can be avoided by appropriate selection of the PMR channels in use in a given area.

5. Type A2 interference: broadcast transmitter sidebands

Interference from sidebands of the broadcast transmitter will be less easily avoided than that from intermodulation products and may prove to be the greater problem.

Consider as before a 1 kW e.r.p. broadcast transmitter with a base-station only 0.1 km away (this and even closer spacings occur in practice). The free space field from the broadcast transmitter at the base-station will be +127 dB (μV/m). If the same wanted signal level and required protection ratio are assumed as before*, it follows that the sideband signals should be less than −130 dBc.

A number of measurements have been made of the sidebands of representative transmitters and drives. In general the levels radiated will depend on the following:

(i) The type of drive and how it is modulated. In particular, synthesiser and crystal drives may be expected to differ in the amount of noise energy close to the carrier.
(ii) The amount of intermodulation noise introduced as a result of non-linearity in the transmitter amplifiers.
(iii) The response of tuned circuits on the output of the final amplifier.
(iv) The response of any combining units between the transmitter and the aerial.

The effect of (iv) is of less significance than might appear. With the configuration in most common use, it is only the lower-frequency transmitters whose sidebands are attenuated by the combining unit. The highest frequency transmitter, which is in any case the most significant interferer in the present context, suffers no attenuation of its upper sidebands in the combining unit.

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* Whether this is valid will depend on the nature of this sideband signal.

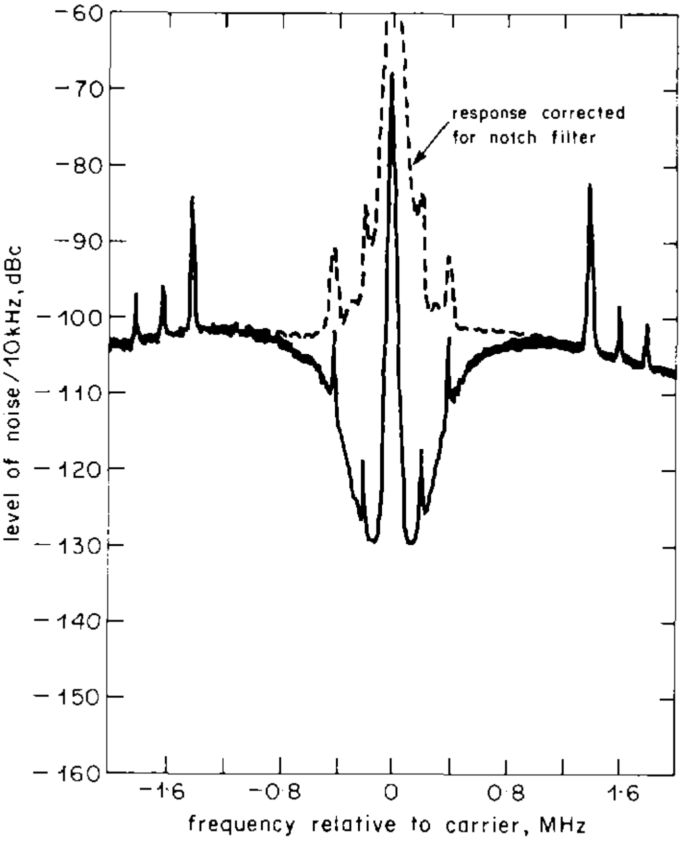

Fig. 4 – Spectrum of broadcast transmitter drive: sidebands close to carrier – no modulation. (measurement notch at carrier frequency, −68 dB).

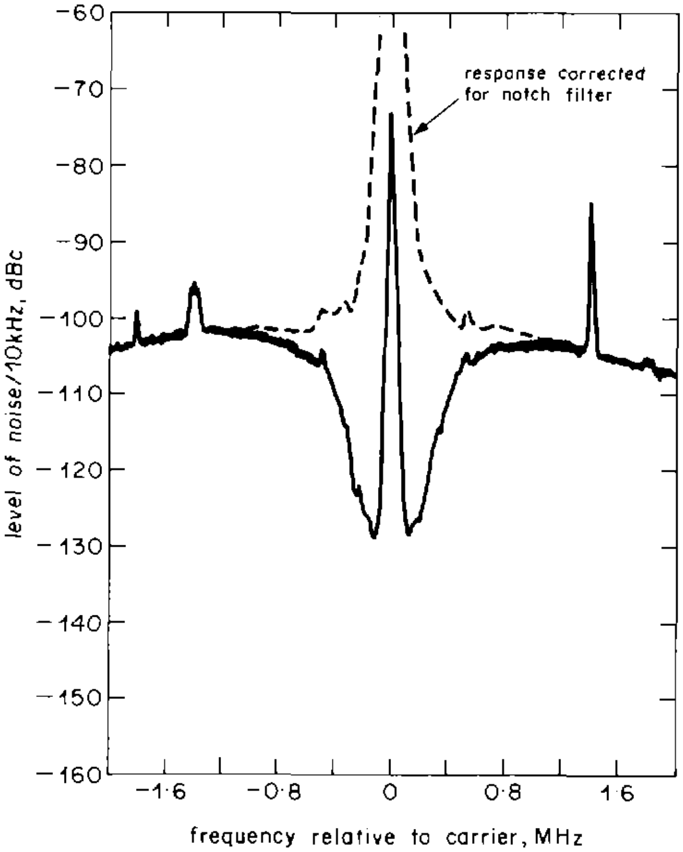

Fig. 5 – Spectrum of broadcast transmitter drive: sidebands close to carrier – with narrow-band deviation. (measurement notch at carrier frequency, −68 dB).

5.1. Drives

Figs. 4 and 6 show the results of measurements on a BBC drive type TM4/2 with no deviation. Figs. 5 and 7 are for the same equipment measured with narrow-band deviation of the carrier (frequency modulation 1 kHz, carrier deviation 7.5 kHz). Fig. 8 gives the response of the carrier-frequency notch filter used in these measurements. It would appear that the *thermal* noise sidebands range from −130 dBc/Hz at ± 100 kHz from the carrier, to −165 dBc/Hz at frequencies more than 6 MHz from the carrier. Superimposed on this noise floor are discrete spurious products at a large number of frequencies, of amplitudes within a typical range of −80 to −110 dBc. Some of these products carry modulation, as can be seen in Figs. 5 and 7 by the reduction of their amplitudes and broadening of their spectrum compared with Figs. 4 and 6 respectively.

5.2. High-power transmitters

Fig. 9 show the results of measurements made on the outputs of three 20 kW transmitters made

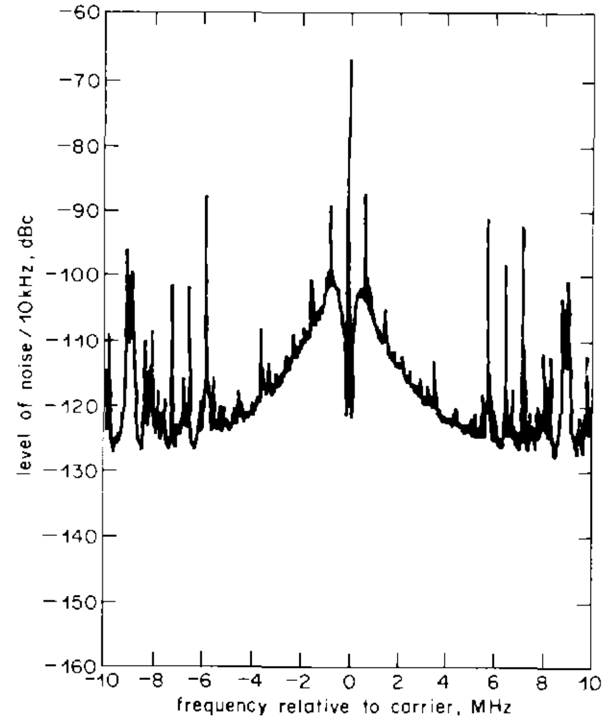

Fig. 6 – Spectrum of broadcast transmitter drive: sidebands remote from carrier – no modulation.

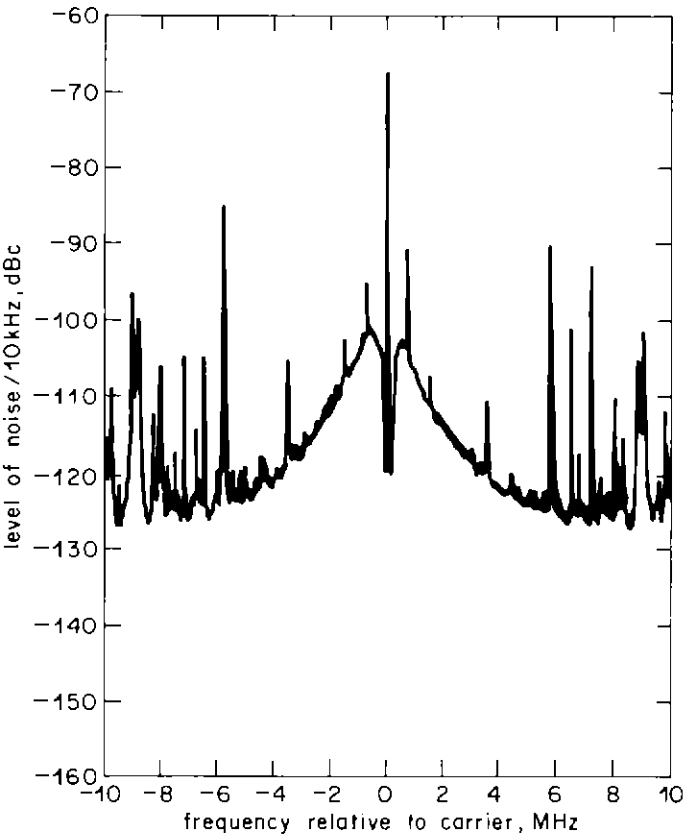

Fig. 7 – Spectrum of broadcast transmitter drive: side-bands remote from carrier – with narrow-band deviation.

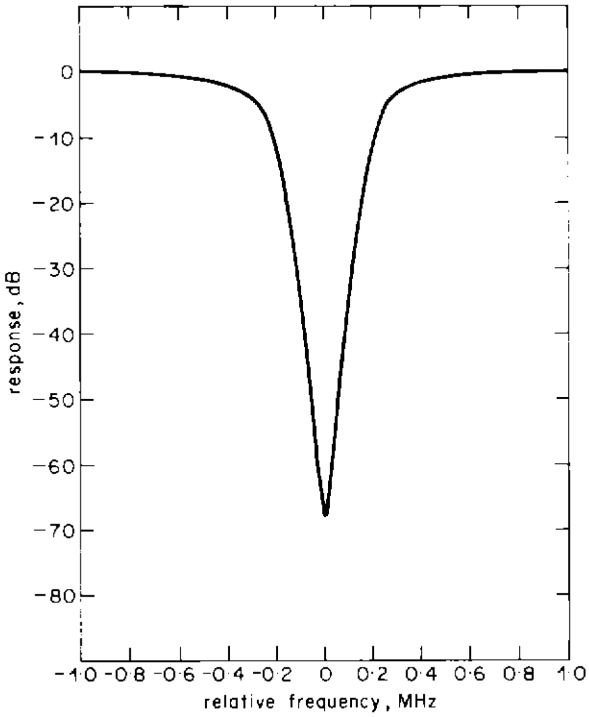

Fig. 8 – Response of notch filter used in measurements of transmitter drive spectra.

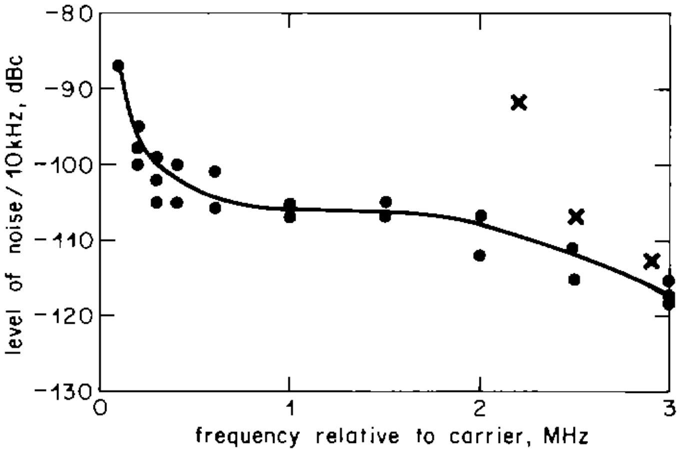

Fig. 9 – Noise side-band and spurious emissions from a high-power broadcast transmitter.

● noise side-band measurement

× 3rd-order intermodulation and spurious emissions

under programme conditions. Each transmitter was excited by a drive of the type discussed in the previous section. It may be seen that the noise floor in the frequency range between 0.2 and 3 MHz from the carrier lies in the range −137 dBc/Hz to −157 dBc/Hz. While these figures are comparable with those of the drive alone, it would appear that the selectivity of the output tuning of the transmitter is beginning to have a noticeable effect for frequency separations from the carrier greater than 2 MHz.

5.3. Medium-power transmitters

Measurements were made on 2 kW amplifiers (BBC type AM14/51A) with drives (BBC type TM4L/5) at the BBC transmitting station at Douglas (Isle of Man). The measurements were made on the final feeder probes so that any response of the combining unit was included. The noise floor measured in a 5 kHz bandwidth was found to be −102 dBc near the carrier frequencies falling, to −120 dBc (the noise floor of the measuring system) at frequencies 2.4 MHz below the lowest carrier and 4.2 MHz above the highest carrier.

5.4. Low-power transmitters

Fig. 10 shows the results of measurements on a 435 W amplifier module (BBC type AM14/45) taken at Knock More. The measurements were taken with a 10 kHz bandwidth and the amplifier was excited by a TM4/2A drive. Fig. 11 shows the response of the low-power combining unit at this site and Fig. 12 shows the calculated overall response of the transmitter on the narrow-band input of the combiner, again with a noise bandwidth of 10 kHz. Unfortunately, Fig. 12 does not apply to the highest fre-

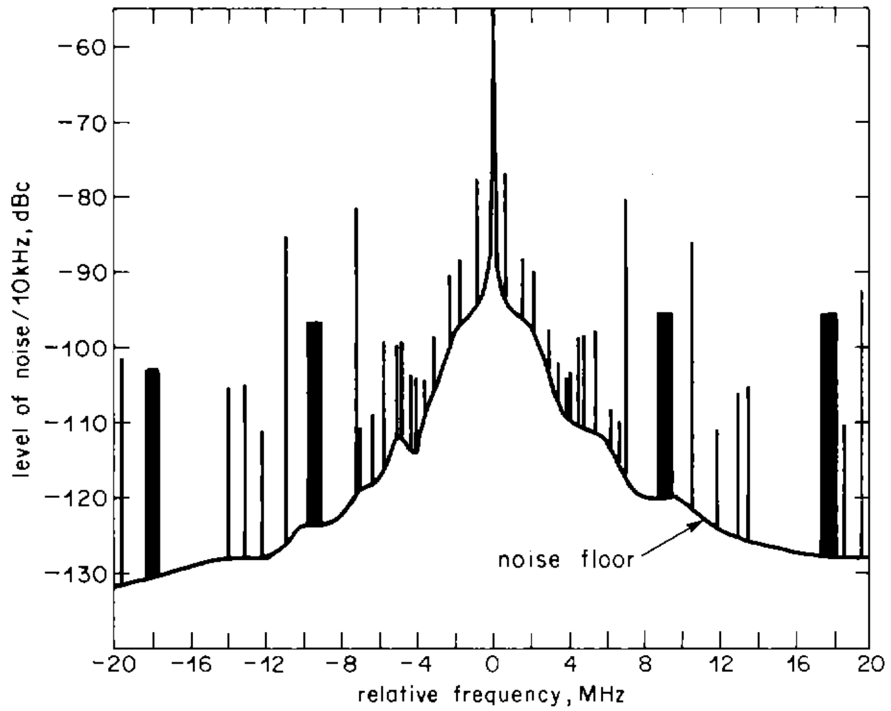

Fig. 10 - Noise side-bands and spurious emissions from a low-power broadcast transmitter.

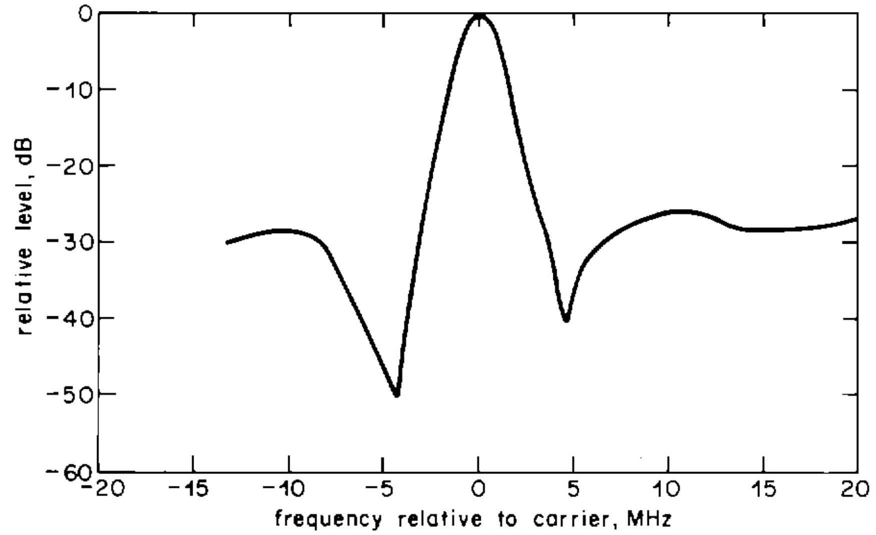

Fig. 11 – Response of a low-power broadcast transmitter combining unit.

quency transmitter, where Fig. 10 is more appropriate.

6. Type B interference: measurements on receivers

Measurements have been made on four receivers. Initially no receiver was available for the frequency band 105–108 MHz but it was thought that representative results would be obtained with receivers for other frequency bands. Accordingly, Receiver 1 was tested for a wanted signal frequency of 77.825 MHz and Receivers 2 and 3 for a wanted signal frequency of 141.8575 MHz.

Later Receiver 4 became available and was tested for a wanted signal frequency of 106.4563 MHz.

6.1. Sensitivity

The level of input signal measured was that required to produce a 12 dB (SINAD)* ratio. The results are given in Table 3.

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*The 'SINAD' method uses the ratio (S + N + D)/(N + D) as a reference magnitude where S, N and D are signal, noise and distortion respectively. The values of both the numerator and denominator are determined in the presence of modulation. When determining the denominator, the desired signal S is removed by the use of a suitable notch filter.

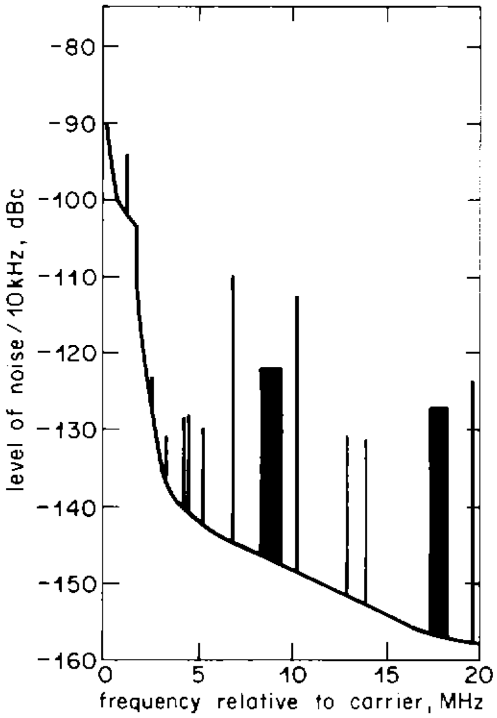

Fig. 12 – Calculated levels of radiated side-bands of a low-power broadcast transmitter.

Table 3 Sensitivity of receivers

Receiver	Modulation	Frequency, MHz	Sensitivity, dBm
1	f.m.	77.825	−122
2	f.m.	141.8575	−121
3	f.m.	141.8575	−117
4	a.m.	106.4563	−111

6.2. B1 interference: intermodulation in receiver

Two signal generators representing broadcasting interferers had frequencies such that third-order intermodulation would be co-incident with the operating frequency of the receiver. One signal generator was modulated with 1 kHz, either 60% amplitude modulation or 1.8 kHz deviation frequency modulation as appropriate, the other being unmodulated. The levels of the generators, which were kept equal, were then adjusted to give a 12 dB SINAD ratio. Fig. 13 shows how the levels varied as a function of frequency spacing.

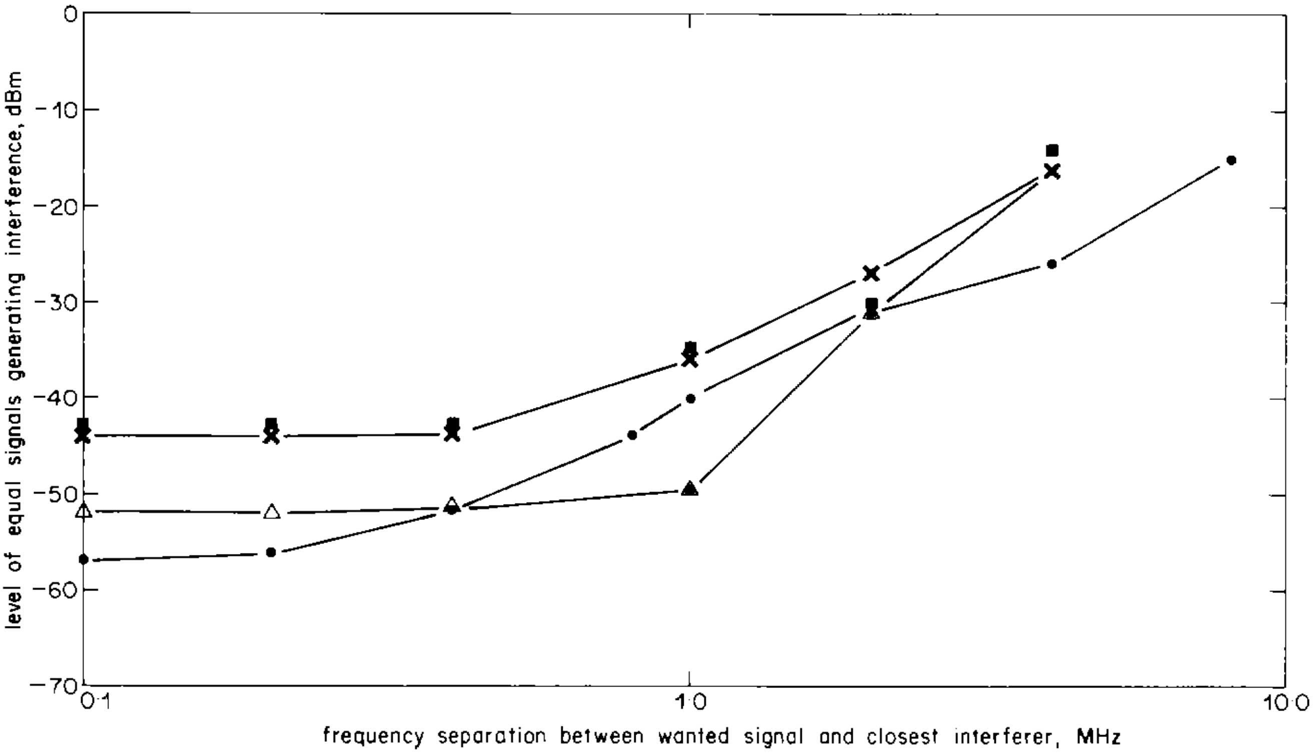

Fig. 13 – Level at which B1 interference in PMR receivers gives SINAD ratio of 12 dB.

× *Receiver 1*
△ *Receiver 2* } *(f.m.)*
■ *Receiver 3*
● *Receiver 4* *(a.m.)*

6.3. B2 interference: breakthrough in receiver

The receivers were set up as above for a 12 dB SINAD ratio. An interfering signal was then introduced at a frequency difference from the wanted signal in the range 100 kHz to 10 MHz. The level of the interference required to give a SINAD ratio of 9 dB (f.m. receiver) or 6 dB (a.m. receiver) was then determined. The results are shown in Fig. 14.

7. Discussion

The various experimental results of measured broadcast transmitter sidebands quoted in section 5 have been given for the noise bandwidths used for the actual measurement. In order to compare the different results it is necessary to standardise on the reference bandwidth. It is convenient to use a value of 10 kHz for this purpose, this being near to the actual bandwidths of PMR receivers likely to be encountered in practice (12.5 kHz and 25 kHz). This value has been used for each of the figures showing noise sidebands so that a comparison of the results can be made more easily. The most significant factor is the wide bandwidth occupied by spurious emissions, particularly so in the case of drives and low power transmitters.

The measurements reported in Section 6 show that relatively low levels of broadcast signals may cause type B1 and B2 interference in the PMR base-station receiver, particularly when the frequency separations between wanted and interfering signals are only a few hundred kilohertz.

The worst case is type B1 interference (intermodulation) and for equal-level interferers requires a receiver input slightly greater than −60 dBm to produce a 12 dB SINAD at its output. At a base-station using a single vertical dipole as a receiving aerial, the corresponding incident field strength at 10 m would be approximately 65 dB (μV/m). With interfering broadcast transmitters having e.r.p.s. of 1 kW and effective heights of 75 m, the land-path separation between them and the base-station required to meet the predicted level would by 12 km. It can often be eliminated by inserting filters to notch out one or more of the broadcast frequencies.

Fig. 14 shows the sensitivity to B2 interference to be less critical than the case above. However, large land-path separations between base-station and broadcast transmitter are needed unless further measures are taken to improve filtering of the receiver input. The sensitivity of the receiver to both forms of interference becomes less as the frequency separation increases.

As a guide to the effect of base-station receiver performance on co-ordination planning, Fig. 15 has been derived from the results shown in Figs. 13 and 14. It gives an example of the physical separation between a broadcast transmitter and a land mobile base-station which might be needed to avoid the

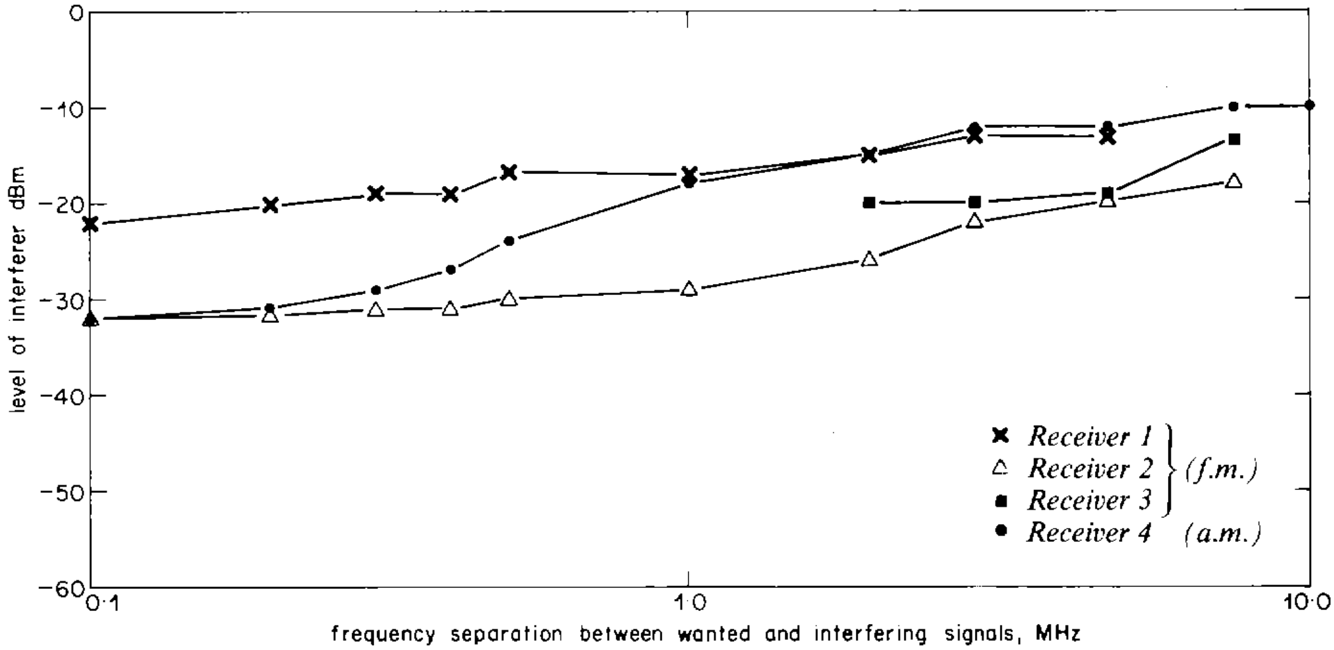

Fig. 14 – Level at which B2 interference in PMR receivers gives SINAD ratio of 9 dB (f.m. receivers) or 6 dB (a.m. receivers).

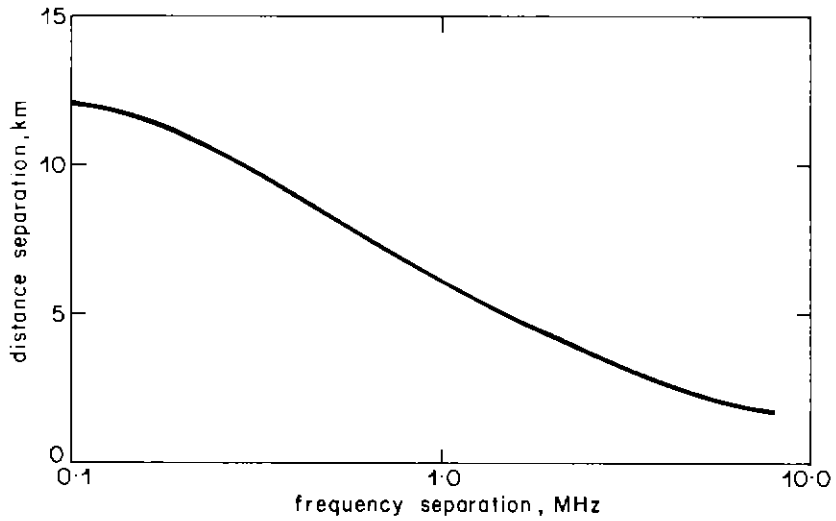

Fig. 15 – Typical distance/frequency separation characteristic between broadcast transmitter and land-mobile base-station necessary to avoid B1 and B2 type interference (without special filtering). (See Section 7).

Transmitter e.r.p.	*1 kW*
Transmitter effective height	*75 m*
Base station receiving aerial height	*3 m*

onset of B1 and B2 type interference in the base-station receivers. The broadcast transmitter is assumed to have an e.r.p. of 1 kW and an effective height of 75 m. However, this result is based on a limited sample of receivers and does not take into account any improvements in receiver input filtering.

Much of the previous discussion has been concerned with the effects of the broadcast transmission on the PMR base-station reception. However, there will be similar modes of interference from PMR mobile transmission on broadcast reception. These will include both B1 and B2 type interference and in addition, in some cases where the broadcast and mobile transmission frequencies differ by 10.7 MHz, the possibility of an intermodulation product equal to the intermediate frequency of the broadcast receiver being generated within the receiver itself.

These interferences will generally be limited to broadcast-receivers situated in the near vicinity of the mobile transmitter. There is little the PMR user can do to alleviate this problem other than observe the ITU specification for spurious emissions[5] from its mobile transmitters and to operate where possible, in the less densely populated area of his operational region. In co-ordinated planning, combinations of broadcast and mobile frequencies which differ by 10.7 MHz should be avoided.

8. Conclusions

Measurements of typical v.h.f. f.m. broadcast transmitter out-of-channel noise and spurious emissions and the out-of-channel characteristics of some v.h.f. PMR receivers have been determined.

Broadcast transmitters are seen to meet the ITU requirements for levels of intermodulation products and spurious emissions. In addition, after critical adjustments of filters and combining units, they can generally meet the lower level recommended by the JIWP. However, the broadcaster will need to monitor the levels of intermodulation products and spurious emissions, and adjust the transmitter circuits if necessary to maintain these emissions below the specified levels.

The noise performance of the transmitters is reasonably good, but the presence of spurious emissions outside the necessary modulation band may cause problems. The level of spurious emission is reduced by the transmitter tuned circuits and the combining networks at the outputs of the transmitters. At present, the upper frequency transmitter output is fed through the wideband input to the combining network and as a consequence there is little attenuation of its noise sidebands. Improvements might be made by the addition of filters in the transmitter outputs or by the use of an extra stage in the combining network, so that all transmitters are combined through narrow-band circuits. Improvements in the transmitter drive design giving a reduction in the number and level of spurious products would also be beneficial. However, it is expected that such improvements would be costly and long term in nature. It is questionable as to whether the broadcaster can maintain a tighter tolerance than the JIWP recommendations on transmitter performance.

The problems of intermodulation and breakthrough interference generated within the PMR receivers are outside of the broadcasters control and it behoves the PMR user to effect a remedy by improving the filtering at the input to base-station receivers. It may be necessary for the user to select channels which avoid both these internally generated intermodulation products and those radiated by the broadcast transmitter which are frequency co-incident with the wanted signal.

Similarly intermodulation and breakthrough interference generated within the broadcast receiver from PMR transmissions are generally beyond the PMR users control. Reception on broadcast receivers in the immediate vicinity of the mobile transmitter may be impaired and it is desirable, where possible, for these operations to be limited to less densely populated areas where fewer listeners will be affected.

There will always be difficulties when the broadcast transmitter and PMR base-stations sites are in close proximity. Most of the difficulties will no longer be a problem once the PMR operations are moved to their new frequencies outside Band II.

9. Acknowledgements

Measurements of the performance of the BBC drive equipment were made by BBC Designs Department. Measurements of sideband noise levels of transmitters and of the performance of PMR receivers were made by Transmitter Capital Projects Department. Acknowledgement is given to staff of both Departments and those of Transmitter and Research Departments involved in the investigation described in this Report.

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10. References

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